

A Gaseous Hydrogen Detector System Based Upon a Solid State Silicon Microsensor

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The Lead Detection for Launch Vehicles program has focused this past year on two vehicle efforts: The DC-XA and the LASRE (Aerospike engine flight test experiment on SR-71 aircraft) programs. Hydrogen leak detection systems have been provided to both of these programs to support flight test operation. The majority of the effort has been spent on the system supplied to MDA for the DC-XA.

The DC-XA system consists of four controller boxes each supervising the operation of eight sensors for a total of 32. Each of the boxes communicates with a ground computer via a launch stand umbilical connection as well as with the flight test telemetry system (FTTS) on the vehicle. This arrangement is shown in the block diagram of figure 81.

Each controller box consists of four printed circuit boards: the microprocessor (MIC) board, the sensor interface (SIF) board, the telemetry (TLM) board and the power (PWR) board. The MIC board contains the microcontroller and the supporting circuitry necessary to supervise and direct the operation of the eight sensors under its control. The SIF board contains the circuitry needed to multiplex the inputs and outputs to and from the microcontroller. The TLM board provides the data buffering necessary to support the electrical and protocol interfaces to the FTTS. The PWR board converts the standard 28 Vdc into the various voltages required by the other three boards. These four boards are stacked up and mounted in an enclosure as shown in figure 82.

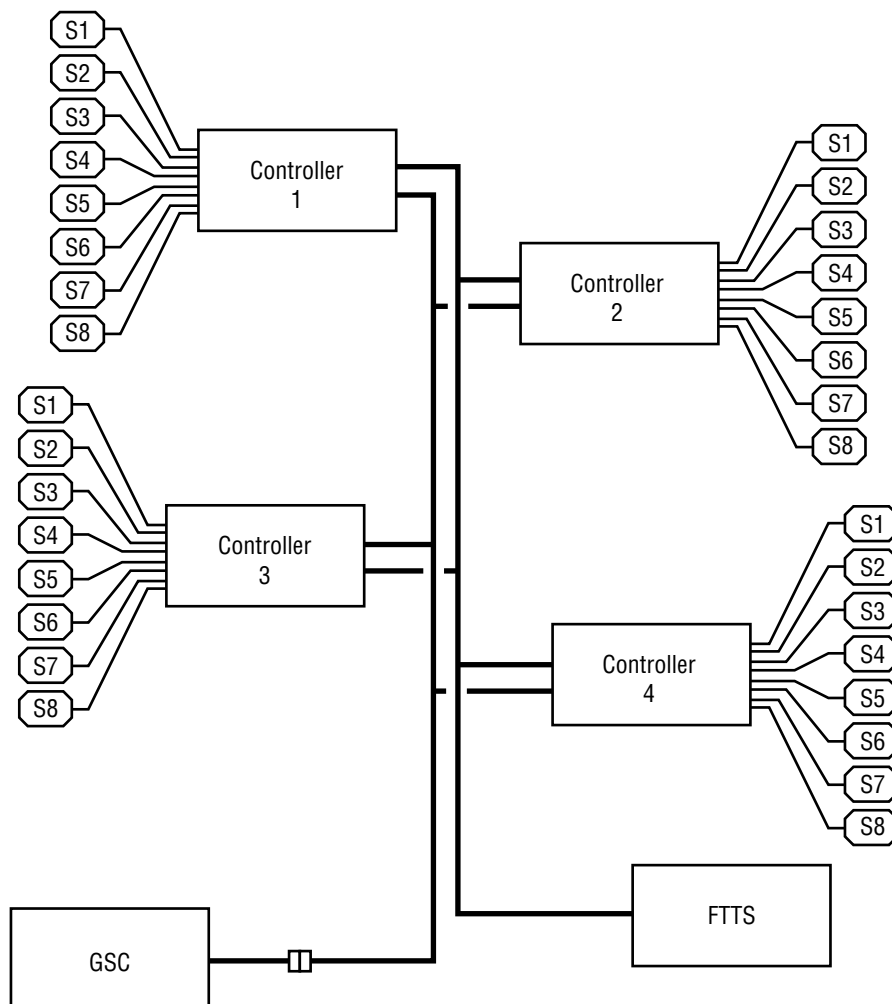


FIGURE 81.—DC-XA connection scheme.

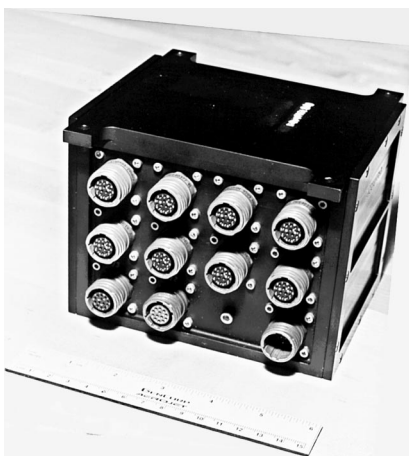


FIGURE 82.—DC-XA controller.

The sensor assemblies consist of a small circuit board that contains the sensing device, an op-amp and some discrete components. The sensing device is a 16-pin dip-style integrated circuit with holes in the lid to allow gas flow to the circuit element and are manufactured by Sandia Labs. The sensors contain a hydrogen-sensitive transistor, a hydrogen-sensitive resistor, a temperature sensor and a heating element. The transistor provides sensitivity to H_2 for very low concentrations, in the range of 0 to 1 percent. The resistor senses H_2 concentrations in the 1- to 100-percent range. The temperature sensor and the heating element are used to maintain a desirable operating temperature for the chip. The circuit board

is mounted in a vented enclosure as shown in figure 83.



FIGURE 83.—DC-XA sensor.

Fabrication, testing and integration support were the tasks involved in supplying the DC-XA leak detection system to MDA.

Fabrication consisted of circuit board assembly, harness assembly and machining of the enclosure. Of the four controller circuit boards needed for each controller, the MIC and the SIF already existed. The PWR board was a new circuit board that closely resembled an existing design. The TLM board was an original design. The MIC, SIF and PWR boards as well as the harness assembly and enclosure machining were performed by Aerojet. The design and construction of the TLM board was performed by MSFC.

Testing of the telemetry interface involved travel to Gulton Data Systems with the assembled system for evaluation in their test setup. This testing revealed an oversight in the communication protocol that was resolved by changes to the microcontroller firmware. Vibration testing exposed a number of mechanical weaknesses in the circuit cards that required substantial rework and repair. Calibration of the system involved temperature calibration of the on-chip temperature sensor. This was followed by exposure of the 32 sensors to various concentrations of hydrogen at controlled temperatures. The calibration data were incorporated into the conversion equations

used to calculate percent H_2 content from the controller's raw 12-bit readings.

Integration support involved checkout and test of the system at Huntington Beach after the system was installed in the vehicle. System signal continuity was checked by applying heat from a heat gun to each of the sensors. This verified the mapping of sensors to physical locations on the vehicles as well as signal integrity. The ground connection through the umbilical and the FTTs connection was also verified.

After the vehicle was delivered to WSMR, effort was spent to establish the ground communications link, configure the ground computer software and operate the system during ground tests and flights.

The original plan had the ground computer in the FOCC area and connected via a fiber-optic modem to the umbilical connection on the stand 3 miles away. This arrangement presented some difficulty in that the protocol of the modems being used was basically incompatible with the protocol used by the four controller boxes. The resolution was to place the ground computer in the GPA trailer at the pad with a direct wire connection to the umbilical. The ground computer was then operated remotely by a second computer in the FOCC area that was serially linked via the modems and the appropriate software package. This resolved the communication issue.

The ground computer software was completed and installed at WSMR. This yielded percent hydrogen readings that compensated for temperature variation. The qualitative nature of the readings seem to indicate consistent operation of the system. While monitoring fueling operations prior to flights 2 and 3, for example, it was observed that procedures such as the initiation of tanking and the onset of the various purges produced responses by the sensors that were uniform, similar and apparently repeatable. The absolute magnitude of the readings, however, was questionable.

After Flight 4 and the loss of the DC-XA vehicle, the telemetry data from the last flight were examined for any suggestion of the presence of excessive hydrogen. The data from one of the four controller boxes were entirely absent from the recorded data stream, and one other box dropped out prior to the end of the flight. The data that were available, however, indicated hydrogen levels no greater than those seen in previous experience.

The SR-71 system is basically a scaled-down version of the DC-XA system. It consists of a single controller box with eight sensors attached. The box communicates with the data logging system through the serial (umbilical) interface. The controller consists of MIC, SIF and PWR boards arranged in an enclosure as shown in figure 84.

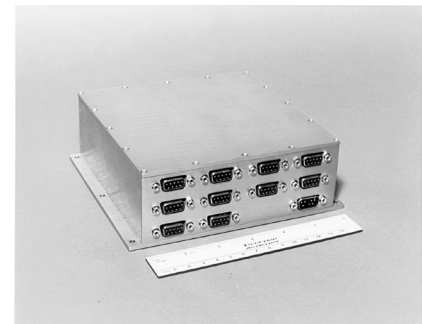


FIGURE 84.—LASRE (SR71) controller.

The development of the SR-71 system made use of existing hardware to the maximum extent possible due to the aggressive delivery schedule. The MIC board came from the original DC-X system and the SIF and PWR boards were spares from the DC-XA effort. The sensor assemblies, shown in figure 85, were also spares that were available. The system was delivered to NASA Dryden in late April. It has not yet been used in support of an engine test.

Sponsor: RLV—Long-Term/High-Payoff Technologies Program

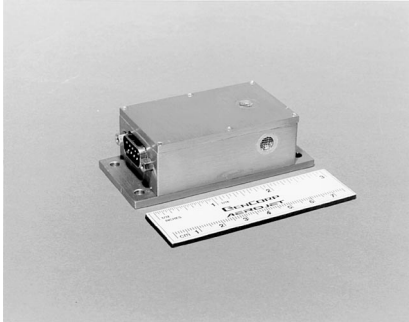


FIGURE 85.—LASRE (SR71) sensor.

Industry Involvement: Gary Paterson/
Aerojet Propulsion

Biographical Sketch: W.T. Powers is a senior measurement systems engineer in the Instrumentation Branch of the Astrionics Laboratory of MSFC. He holds a bachelor of science in electrical engineering, minors in mechanical, nuclear and physics, from Tennessee Polytechnic Institute. Powers has 33 years service with NASA, and primarily deals with development of advanced sensors and measurement, acquisition, and processing systems. ●